Star's Name.	Dr. Huggins' Results.	Ten-prism Spectroscope. Results.	Ten-prism Spectroscope. Weight.	Half-prism Spectroscope. Results.	Half-prism Spectroscope. Weight.
ϵ Ursæ Majoris	+ 17 to 21	+	6		
α Virginis	+	+	4	0	16
ζ Ursæ Majoris	+ 17 to 21	+	6		
η Ursæ Majoris	+	−32	7		
η Boötis				−	4
Arcturus	−55	−41	73	−18	30
ϵ_2 Boötis		+ 1	21	−	9
α Coronæ	+	+38	13	+58	14
β Herculis		−	3		
α Herculis		−31	$5\frac{1}{2}$		
β Draconis		+ 7	$1\frac{1}{2}$		
α Ophiuchi		?		?	
γ Draconis		−18	$14\frac{1}{2}$		
α Lyræ	−44 to 54	−37	92		
ζ Aquilæ		?		−	9
γ Aquilæ		−	1	−	5
δ Cygni		−23	12		
α Aquilæ		?			
γ Cygni	−	−20	$24\frac{1}{2}$	−	$2\frac{1}{2}$
α Cygni	−39	−41	40	−	7
ϵ Cygni		+13	$3\frac{1}{2}$	+	4
ϵ Pegasi		−24	$11\frac{1}{2}$		
Fomalhaut		?			
β Pegasi		+20	10		
α Pegasi	−	−22	16		

Royal Observatory, Greenwich,
1878, *June* 14.

On the Photographs of the Transit of Venus.
By Captain G. L. Tupman, R.M.A.

(*Communicated by the Astronomer Royal*).

The photographs that have been measured were taken with the five Photoheliographs made by Mr. Dallmeyer for the Transit of *Venus* Expeditions on "Patent Plates," 6 inches square, the images of the Sun being very nearly 3·9 inches in diameter. The Dry process of Captain Abney, R.E., described in the *Monthly Notices*, vol. xxxiv., p. 275, was used throughout.

The measuring instrument, designed by the Astronomer Royal for the purpose, the determination of the errors of graduation of its glass millimeter scale, and the method of obtaining the optical distortion of the Photoheliographs are sufficiently described in vol. xxxvi., p. 178. It was found by an elaborate investigation that the lines of equal distortion were sensibly circles concentric with the centre of the field. The actual correction for distortion for that zone of the field in which the points to be measured generally fall is shown in the following table. By the scale adopted, the distortion is taken as zero at the centre of the field and at the distance of about 47 millimeters from the centre. One millimeter corresponds to about 19·5 seconds of arc.

Distance from centre of field in millimeters	Luxor instrument.	Honolulu instrument.	Rodriguez instrument.	Burnham instrument.	Kerguelen instrument
	mm.	mm.	mm.	mm.	mm.
40	+·040	+·034	+·045	+·040	+·042
42	+·030	+·025	+·033	+·030	+·032
44	+·019	+·015	+·021	+·020	+·021
46	+·006	+·005	+·008	+·007	+·009
48	−·006	−·007	−·006	−·006	−·003
50	−·021	−·019	−·020	−·020	−·017
52	−·037	−·032	−·036	−·036	−·031

Before commencing the measures of a negative, the position of the line of centres was marked upon the film by a simple mechanical process. This operation was performed independently by Mr. Burton and myself with no sensible difference. In placing the negative in the instrument, the circular carrier was turned about until the line of centres was truly parallel to the direction of the sliding motion of the microscopes.

When the negatives are placed under the microscope with an amplification of only 5 or 6 diameters, the limbs of both planet and Sun, even those which are pretty sharp to the unaided eye, become extremely indistinct, and the act of bisecting the limb with the wire or cross of the micrometer is mere guesswork. The deposit of silver fades off gradually to nothing, and the denser the film the broader is the zone of fading off, and the more uncertain the measures. In many cases the difficulty is aggravated by ruggedness due to atmospheric disturbances, but the smooth and gradual fading off is the chief cause of uncertainty.

There is only *one* really sharp image in the whole collection, including the Indian and Australian contingents, and that is one of Captain Waterhouse's wet plates taken at Roorkee with a Dallmeyer instrument precisely similar to the others.

It should be remarked that in these instruments the artist has attempted to unite the photographic and visual foci on the collodion film. No doubt some sharpness of the photographic

image was thus sacrificed, but this has little or nothing to do with the unfortunate failure in the application of photography. Each photograph was measured six times by Mr. Burton and six times by me. I was not able to include in my series of measures all the photographs measured by Mr. Burton, for the reason that, when some of them were viewed through the microscope, there was nothing visible to bisect, either from the extreme faintness of the film or from its too gradual fading off. Mr. Burton generally employed a cross of webs, but I preferred a single very fine web, the breadth of which was eliminated in the mean by the mode of bisecting.

It has been suggested that the instrument should possess the power of rotating the Sun's image about a mechanical centre. This would be useful in some cases of ruggedness, but, in my opinion, would make no material difference in the accuracy of measurement. The rotation could only be applied to the limbs of the Sun,* whereas perhaps the greatest difficulty is with the limbs of the planet.

From the measures, corrected for distortion, are obtained the photographic diameters of the Sun and of *Venus*; the former presumably enlarged, the latter diminished by irradiation, in a sensibly equal degree. The sum of the measured diameters in millimeters is compared with the sum of the tabular diameters, subject to errors, for the scale value, and thus every photograph furnishes its own scale. The measured distance of centres *in arc*

$$\mathrm{M} = \frac{\text{distance of centres in millimeters} \times \text{sum of tabular diameters}}{\text{sum of measured diameters in millimeters}}.$$

This relation will be true, except when the Sun is near the horizon. As long as the refraction for the centre is sensibly the mean between the refraction at the upper and lower limbs, its effect upon distance of centres will be eliminated.

If $d\mathrm{R}$, dr be the corrections required to the Tabular Semi-diameters R, r of the Sun and *Venus* respectively; Δ the Local Tabular distance of centres; and if the True Mean Solar Parallax = Tabular M. S. Parallax $\left(1+\frac{n}{100}\right)$, we have for each photograph, neglecting errors of longitude,

$$\text{True distance of centres} = \mathrm{M} + \frac{\mathrm{M}}{\mathrm{R}+r}(d\mathrm{R}+dr) = \Delta + \mathrm{A}\,.\,n + \mathrm{B}\,.\,d\mathrm{RA} + \mathrm{C}\,.\,d\mathrm{NPD}.$$

The coefficients A, B, C, D have been computed for each photograph by the formulæ given in the *Monthly Notices*, vol. xxxv., p. 277. The equations thus obtained were formed into groups of about 10, and the means taken as below:—

* And only with sensibly circular images such as those obtained with a high Sun.

(1) From Mr. Burton's measures—

	″ ″	No. of Photos.
Thebes	$6.06 = -.1413\,n - .0422\,d\mathrm{RA} - .9985\,d\mathrm{NPD} - .8571\,(d\mathrm{R}+dr)$	11
	$5.82 = -.1629\,n - .1188\,d\mathrm{RA} - .9914\,d\mathrm{NPD} - .8818\,(d\mathrm{R}+dr)$	11
	$6.40 = -.1773\,n - .1782\,d\mathrm{RA} - .9810\,d\mathrm{NPD} - .9071\,(d\mathrm{R}+dr)$	11
Honolulu	$8.99 = -.2280\,n + .6286\,d\mathrm{RA} - .7318\,d\mathrm{NPD} - .9200\,(d\mathrm{R}+dr)$	11
	$8.86 = -.2263\,n + .5998\,d\mathrm{RA} - .7596\,d\mathrm{NPD} - .9009\,(d\mathrm{R}+dr)$	11
	$8.30 = -.2181\,n + .5342\,d\mathrm{RA} - .8139\,d\mathrm{NPD} - .8681\,(d\mathrm{R}+dr)$	10
Rodriguez	$5.58 = +.1725\,n + .5500\,d\mathrm{RA} - .8025\,d\mathrm{NPD} - .9003\,(d\mathrm{R}+dr)$	11
	$6.85 = +.1423\,n + .4640\,d\mathrm{RA} - .8633\,d\mathrm{NPD} - .8682\,(d\mathrm{R}+dr)$	10
	$4.90 = +.0902\,n + .3032\,d\mathrm{RA} - .9380\,d\mathrm{NPD} - .8398\,(d\mathrm{R}+dr)$	10
	$5.13 = +.0053\,n - .0119\,d\mathrm{RA} - .9985\,d\mathrm{NPD} - .8610\,(d\mathrm{R}+dr)$	11
	$3.34 = -.0140\,n - .1139\,d\mathrm{RA} - .9920\,d\mathrm{NPD} - .8899\,(d\mathrm{R}+dr)$	11
Burnham	$6.70 = +.0300\,n + .4803\,d\mathrm{RA} - .8508\,d\mathrm{NPD} - .8729\,(d\mathrm{R}+dr)$	13
Kerguelen	$5.34 = +.1669\,n + .3042\,d\mathrm{RA} - .9438\,d\mathrm{NPD} - .8440\,(d\mathrm{R}+dr)$	8

From these, considered as of equal weight, we have the three normal equations,

$$\begin{aligned}
-\ 5''.352 &= +.3159\,n - .0836\,d\mathrm{RA} + .4726\,d\mathrm{NPD} + .5147\,(d\mathrm{R}+dr)\\
+25.446 &= -.0836\,n + 2.0340\,d\mathrm{RA} - 2.7129\,d\mathrm{NPD} - 2.9968\,(d\mathrm{R}+dr)\\
-72.327 &= +.4726\,n - 2.7129\,d\mathrm{RA} + 10.5821\,d\mathrm{NPD} + 10.2255\,(d\mathrm{R}+dr);
\end{aligned}$$

and their solution is

$$\begin{aligned}
n &= -7.88 - .233\,(d\mathrm{R}+dr),\\
d\mathrm{RA} &= +5''.38 + .287\,(d\mathrm{R}+dr),\\
d\mathrm{NPD} &= -5.10 - .882\,(d\mathrm{R}+dr);
\end{aligned}$$

whence the mean Solar Parallax $= 8''.25 - .021\,(d\mathrm{R}+dr)$.

(2) From my own measures—

	″ ″	No. of Photos.
Thebes	$5.02 = -.1567\,n - .0966\,d\mathrm{RA} - .9930\,d\mathrm{NPD} - .8753\,(d\mathrm{R}+dr)$	12
	$5.85 = -.1773\,n - .1782\,d\mathrm{RA} - .9810\,d\mathrm{NPD} - .9071\,(d\mathrm{R}+dr)$	11
Honolulu	$8.00 = -.2280\,n + .6275\,d\mathrm{RA} - .7329\,d\mathrm{NPD} - .9182\,(d\mathrm{R}+dr)$	12
	$8.26 = -.2259\,n + .5949\,d\mathrm{RA} - .7641\,d\mathrm{NPD} - .8974\,(d\mathrm{R}+dr)$	12
Rodriguez	$5.08 = +.1738\,n + .5537\,d\mathrm{RA} - .7996\,d\mathrm{NPD} - .9016\,(d\mathrm{R}+dr)$	9
	$4.99 = +.1444\,n + .4704\,d\mathrm{RA} - .8595\,d\mathrm{NPD} - .8680\,(d\mathrm{R}+dr)$	6
	$4.56 = +.1058\,n + .3556\,d\mathrm{RA} - .9223\,d\mathrm{NPD} - .8407\,(d\mathrm{R}+dr)$	8
	$4.21 = +.0036\,n - .0197\,d\mathrm{RA} - .9986\,d\mathrm{NPD} - .8620\,(d\mathrm{R}+dr)$	10
	$2.59 = -.0141\,n - .1142\,d\mathrm{RA} - .9921\,d\mathrm{NPD} - .8890\,(d\mathrm{R}+dr)$	9
Burnham	$5.77 = +.0179\,n + .5699\,d\mathrm{RA} - .7862\,d\mathrm{NPD} - .9072\,(d\mathrm{R}+dr)$	3
	$6.05 = +.0336\,n + .4494\,d\mathrm{RA} - .8702\,d\mathrm{NPD} - .8619\,(d\mathrm{R}+dr)$	10

From these, weighted as the square root of the number of photographs, are obtained the normal equations,

$$
\begin{aligned}
-\ 46''\!\cdot\!84 &= +2''\!\cdot\!377\,n - 1\cdot029\,d\mathrm{RA} + 4\cdot388\,d\mathrm{NPD} + 5\cdot231\,(d\mathrm{R}+dr)\\
+188\cdot09 &= -1\cdot029\,n + 17\cdot680\,d\mathrm{RA} - 21\cdot002\,d\mathrm{NPD} - 24\cdot232\,(d\mathrm{R}+dr)\\
-496\cdot40 &= +4\cdot838\,n - 21\cdot002\,d\mathrm{RA} + 81\cdot112\,d\mathrm{NPD} + 79\cdot868\,(d\mathrm{R}+dr);
\end{aligned}
$$

and their solution is

$$
\begin{aligned}
n &= -9\cdot70 - \cdot445\,(d\mathrm{R}+dr),\\
d\mathrm{RA} &= +5''\!\cdot\!04 + \cdot298\,(d\mathrm{R}+dr);\\
d\mathrm{NPD} &= -3\cdot36 - \cdot881\,(d\mathrm{R}+dr);
\end{aligned}
$$

whence the Mean Solar Parallax $= 8''\cdot08 - \cdot040\,(d\mathrm{R}+dr)$.

These values of the parallax being quite inadmissible, the Astronomer Royal suggested that the tolerably well-known values of n, dRA, and dNPD, obtained from the contact observations, should be substituted in the equations, so that the outstanding quantities might appear as errors of the distance of centres or of the photographic semidiameters. Accordingly, n being taken $-\ 1\cdot117$, corresponding to the mean solar parallax $8''\cdot85$, $d\mathrm{RA} = +5''\cdot81$, $d\mathrm{NPD} = -5''\cdot33$, the following equations result:—

Station.	From Burton's measures.	No. of Photos.	From Tupman's measures.	No. of Photos.
Thebes	$\cdot857\,(d\mathrm{R}+dr) = -0''\cdot83$	11		
	$\cdot882\,(d\mathrm{R}+dr) = -1\cdot04$	11	$\cdot875\,(d\mathrm{R}+dr) = -0''\cdot11$	12
	$\cdot907\,(d\mathrm{R}+dr) = -2\cdot01$	11	$\cdot907\,(d\mathrm{R}+dr) = -1\cdot46$	11
Honolulu	$\cdot920\,(d\mathrm{R}+dr) = -1\cdot18$	11		
	$\cdot901\,(d\mathrm{R}+dr) = -1\cdot07$	11	$\cdot918\,(d\mathrm{R}+dr) = -0\cdot19$	12
	$\cdot868\,(d\mathrm{R}+dr) = -0\cdot61$	10	$\cdot897\,(d\mathrm{R}+dr) = -0\cdot48$	12
Rodriguez	$\cdot900\,(d\mathrm{R}+dr) = +1\cdot07$	11	$\cdot902\,(d\mathrm{R}+dr) = +2\cdot20$	9
	$\cdot868\,(d\mathrm{R}+dr) = +0\cdot29$	10	$\cdot868\,(d\mathrm{R}+dr) = +2\cdot16$	6
	$\cdot840\,(d\mathrm{R}+dr) = +1\cdot76$	10	$\cdot841\,(d\mathrm{R}+dr) = +2\cdot30$	8
	$\cdot861\,(d\mathrm{R}+dr) = +0\cdot12$	11	$\cdot862\,(d\mathrm{R}+dr) = +1\cdot09$	10
	$\cdot890\,(d\mathrm{R}+dr) = +1\cdot30$	11	$\cdot889\,(d\mathrm{R}+dr) = +2\cdot05$	9
Burnham	$\cdot873\,(d\mathrm{R}+dr) = +0\cdot59$	13	$\cdot907\,(d\mathrm{R}+dr) = +1\cdot71$	3
			$\cdot862\,(d\mathrm{R}+dr) = +1\cdot19$	10
Kerguelen	$\cdot844\,(d\mathrm{R}+dr) = +1\cdot27$	8		0

The discordances here shown are of three kinds:—

1° Taking the Rodriguez results by themselves, as they are the most numerous and the photographs present the sharpest limbs, Mr. Burton's measures show a discordance of $1''\cdot6$ between the means of two contiguous groups. My measures also have

the greatest discordance, $1''\cdot 2$, between the same groups. These discordances are obviously due to the inherent defects of the photographic images, and are of such magnitude as to forbid the employment of the measures in the determination of the solar parallax.

2° There is a curious systematic difference between Mr. Burton and myself amounting to nearly $1''$. Mr. Burton invariably placed the negative in the measuring instrument with the planet on the left-hand side of the Sun's centre, whereas I always placed it with the planet on the right-hand side. It is difficult to conceive, however, in what manner this can have affected our appreciation of the diameters or of the distance of centres.

3° There is a systematic difference between the Northern and the Southern stations of a very puzzling character, affecting the distance of centres to the extent of about $2''$, or about one-twelfth part of the total relative parallactic displacement of the planet referred to the centre of the Sun. No cause for this has at present been suggested. These discordances support the decision of the American Commission that the photographic diameter of the Sun cannot be relied on when accuracy is required.

Additions and Corrections to Captain Tupman's Paper in the Monthly Notices for June 1878.

Page 449, line 18. The normal equations are

$$+31\cdot0000\, i - 0''\cdot0787\, n = -8''\cdot3328,$$
$$-\ 0\cdot0787\, i + 0\cdot6112\, n = -0\cdot5744.$$

Page 450, line 22. The normal equations are

$$+28\cdot0000\, i - 0''\cdot2055\, n = -1''\cdot7466,$$
$$-\ 0\cdot2055\, i + 0\cdot6565\, n = -0\cdot7581\,;$$

whence

$$i = -0''\cdot177, \qquad n = -1\cdot071.$$

Page 453, line 2. The normal equations are

$$+55\cdot0000\, e + 0''\cdot9377\, n = -0''\cdot6794,$$
$$+\ 0\cdot9377\, e + 1\cdot0793\, n = -1\cdot2416.$$

Page 454, line 11. The normal equations are

$$+48\cdot0000\, e + 1''\cdot5013\, n = -3''\cdot7696,$$
$$+\ 1\cdot5013\, e + 0\cdot9343\, n = -0\cdot6729.$$